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Washington, D. C. ▼ June, 1926

THE PINK BOLLWORM,[1] WITH SPECIAL REFERENCE TO STEPS TAKEN BY THE DEPARTMENT OF AGRICULTURE TO PREVENT ITS ESTABLISHMENT IN THE UNITED STATES.[2]

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HISTORICAL

In 1842 the superintendent of the Government cotton plantations at Broach, India, sent specimens of a very destructive cotton insect to the distinguished English entomologist, W. W. Saunders. The specimens were described as a new species, *Depressaria* (now *Pectinophora*) *gossypiella*, by Saunders in a paper presented to the Entomological Society of London on June 6, 1842 (*18*).[4] This is the first published record concerning the insect which is now attracting so much attention in the principal cotton-producing countries of the world.

For 61 years after the publication of Saunders' description no published statement regarding the pink bollworm was issued. In 1904, however, an article was issued by J. Vosseler (*20*) regarding the great injury caused by the insect in German East Africa. With-

[1] *Pectinophora gossypiella* Saunders; order Lepidoptera, family Gelechiidae.

[2] This bulletin supersedes Department Bulletin 723, issued under the same title in 1918.

[3] Died October 13, 1925. The manuscript of this bulletin had its final revision by the author June 22, 1925.

[4] Numbers (italic) in parentheses refer to "Literature cited," p. 29.

in the next few years several additional articles dealing with the problem caused by the pest in German East Africa appeared. In 1909 D. T. Fullaway (*8*) published an account of the pink bollworm and its relation to cotton culture in the Hawaiian Islands, stating that it appeared to have been introduced from India within "comparatively recent" years.

Only a few more or less technical papers were published from 1909 to 1913. Since the latter date a considerable literature has been built up, consisting largely of papers emanating from Egypt, where the pest has attracted increasing attention.

ORIGINAL HOME

The original home of the pink bollworm is probably India and possibly southern Asia generally, and its original host plants were the wild and cultivated cottons of that region. This conclusion, published by the writer (*13*) in an earlier bulletin on this subject, was also announced by Marlatt (*15*) at about the same time, after a more exhaustive discussion of the evidence available. If this natural range of the insect extended to Africa it must have been limited to central Africa and at least it did not extend to the Nile Valley region, where cotton has been an important cultivated crop for a century or more. The occurrence of the insect in Egypt is apparently traced definitely to large shipments of seed cotton or imperfectly ginned cotton from India in 1906–7, and the spread of the insect from the points in the lower Delta, near Alexandria, where this cotton was sent for reginning, throughout the Delta, and ultimately throughout Egypt, is so well confirmed by circumstantial evidence as to leave no doubt as to the entry of the insect at that time into Egypt. With the first occurrence of the insect in Egypt it was confused more or less with other insects commonly found in cotton bolls in that country, and this confusion led to a statement by Dudgeon (*6*) that this insect had probably been in Egypt for many years. The careful investigation of the situation and determination of original points of infestation and spread by expert entomologists in the employ of the British and Egyptian Governments have fully disproved this early surmise and pointed out the real manner of introduction of the insect into Egypt.

As already noted, the pink bollworm has been recorded as a cotton pest in India since 1842, and the original report made by the superintendent of the Government cotton plantation at Broach, India, is of sufficient importance to be given in full, as follows:

> The inclosed is an insect which was very destructive to the American cotton which was sown here (Broach) on light alluvial soil. The egg is deposited in the germen at the time of flowering, and the larva feeds upon the cotton seed until the pod is about to burst, a little previous to which time it has opened a round hole in the side of the pod for air, and at which to make an exit at its own convenience, dropping on the ground, which it penetrates about an inch, and winds a thin web in which it remains during the aurelia state. Curious enough, the cotton on the black soil was not touched by it. The native cotton is sometimes affected by it.

The significant thing in the paragraph is the statement that the insect was very destructive to the American cotton and that "*native cotton is sometimes affected by it.*" The fact that the American cotton was much more affected than the native varieties is in accord

with the general experience with imported plants in relation to native plant pests, and with introduced pests in respect to native plants. The American variety was apparently unresistant in comparison with the native cottons of India, which, with little doubt, had been long associated with this pest and had developed a certain degree of resistance.

The later records of this insect show that it was reported from India on several occasions prior to 1900, or about that period, and those records confirmed also its occurrence eastward through Burma, Siam, and the Philippines, long previous to what was undoubtedly its original entry into Egypt in 1906–7.

The insect was first observed in Egypt in 1911, and the first severely infested field, one near Alexandria, was noted in 1912. The increase of the damage from this insect in Egypt has been steady since 1912, in spite of very laborious and expensive control operations enforced by the Egyptian Government.

The present distribution of the pink bollworm is therefore reasonably traceable to its spread from southern Asia in comparatively recent years. The possible exception may be found in German East Africa, and even there the natural explanation of its occurrence is its recent introduction with cotton imported from India. It is, however, possible that the natural range of the insect may have included central Africa and that the African infestation may therefore have come from native stock.

PRESENT RANGE

With the exception of certain infestations in Texas and New Mexico, the known range of the pink bollworm is as follows:

East Africa, west Africa, Egypt, Angola, Italian Somaliland, Nigeria, Sierra Leone, Sudan, Zanzibar, India (very generally), Bengal, Ceylon, Burma, Siam, Straits Settlements, China, Korea, Philippines (Luzon), Hawaii, Brazil, West Indies (St. Croix, St. Kitts, Anguilla, Monserrat, Porto Rico, Santo Domingo, Haiti, St. Vincent), Mexico, and Australia. There is also a record from Japan, although it may be erroneous. At any rate, according to a statement published by Fullaway (*8*), it is not confirmed by Professor Kuwana, Government entomologist. Another doubtful record is from Mesopotamia.[5]

The introduction of the pink bollworm into Brazil and Mexico is recent, and available records show very clearly how it was accomplished. The information from Brazil comes through Edward C. Green, formerly superintendent of the cotton department of the Brazilian Ministry of Agriculture, who has published a very full statement on the subject (*11*). In 1913 Green made a trip of inspection through the greater portion of the cotton-producing area in Brazil. Special attention was paid to the seed, not only in the fields but in the ginneries, and no infestation was found. In 1916, however, another trip showed that the pink bollworm was present over wide areas in the States of Parahyba, Rio Grande del Norte, and Ceara. It seems that in the years 1911, 1912, and 1913, the

[5] For a complete statement concerning the distribution of the pink bollworm, with citations, see the Second Annual Report of the Egyptian Cotton Research Board, 1921, pp. 136–137.

Government of Brazil imported 9 tons of Egyptian cottonseed. This seed was not fumigated, as it was not suspected that any injurious insect was likely to be carried by it. A test for germination showed 89 per cent viable. It is altogether probable that a large percentage of the unviable seeds were those attacked by the pink bollworm. All of this seed was sent to agricultural inspectors in various States and by them was distributed further throughout the cotton-growing districts. There can be no doubt that the general establishment of the pink bollworm in Brazil was due to the importation of the Egyptian seed, and that incalculable losses to the country could have been avoided if proper quarantine precautions had been taken.

In 1911 two importations of Egyptian seed were brought into Mexico; one, of 25 sacks, was planted near Monterey, and the other, of 6 tons, in the vicinity of San Pedro, in the Laguna district. From what is known of the prevalence of the pink bollworm in Egypt in 1911 it is probable that both shipments of seed were infested and that both of them contributed to the present infestation in Mexico. It is true that cotton culture has not been continued in the vicinity of Monterey, but the crop of Egyptian cotton produced there in 1911 attracted considerable attention and much of the seed was shipped to the Laguna district.

In 1917, specimens of the pink bollworm, collected by H. H. Jobson, were received from China. Following is a quotation from Jobson's notes:

> The collection which I have was secured from the seed room of one of the ginneries in Shanghai and from the fields at Tungchow, about 12 hours' ride by boat up the river from Shanghai. The infestation is more or less general throughout China; however, there may be some small areas where it is not present. A majority of the cotton grown within a radius of 100 miles of Shanghai is shipped into that port before being ginned, and from evidences found at the ginning establishments there is no doubt but what all those regions are infested. In fact, the larvæ are so numerous that by going into the seed room of the gins a person may secure any number of them within a very short time, as they may be seen crawling around over the seed and on the walls.

The infestation in Australia was first reported in 1923, from Queensland, and appears to have resulted from the carriage of cottonseed by soldiers returning from Europe to Australia, who stopped at Alexandria, Egypt.

The infestation in the West Indies was apparently caused by a small shipment of cottonseed imported from Hawaii in 1911 to be used on the island of St. Croix for experimental purposes.

PRESENT DISTRIBUTION IN MEXICO

As far as is shown by absolutely definite evidence, the pink bollworm in Mexico is confined to localities in the northern part of that country, one of them being the Laguna district, a valley isolated by mountain ranges about 200 miles from the Texas border. The Laguna, in which the greater part of the Mexican cotton crop is produced, consists of about 1,200 square miles of tillable land. Other localities known to be infested in Mexico (fig. 11, p. 26) are Allende (about 40 miles south of Eagle Pass), the Trevino Ranch (immediately opposite Del Rio), Santa Rosalia (in Chihuahua), Monclova, the Juarez Valley, and the area in Chihuahua opposite

Presidio and Brewster Counties, Tex. In all these cases the infestations were caused by seed from the Laguna. The insect has frequently been found alive in freight cars coming from the interior of Mexico to Texas border ports.

DESCRIPTION AND LIFE HISTORY

The pink bollworm has four stages; namely, egg, larva, pupa, and adult, or moth. The moth (fig. 1) resembles somewhat the common clothes moth of this country. From tip to tip of the extended wings it measures from three-fifths to four-fifths of an inch. It is of a dark-brown color, the forewings ending in a rather sharp point. The hindwings are somewhat broader than the forewings and end in an even sharper point. The eggs are very small objects, somewhat oval, about one-twenty-fifth of an inch long and one-fiftieth of an inch broad. The surface is white and finely wrinkled. The larva (fig. 2) when first hatched is glassy white with light-brown anterior markings. It grows rapidly, and when mature measures nearly a half inch in length. It is cylindrical, white, with the dorsal side of a strong pink color.

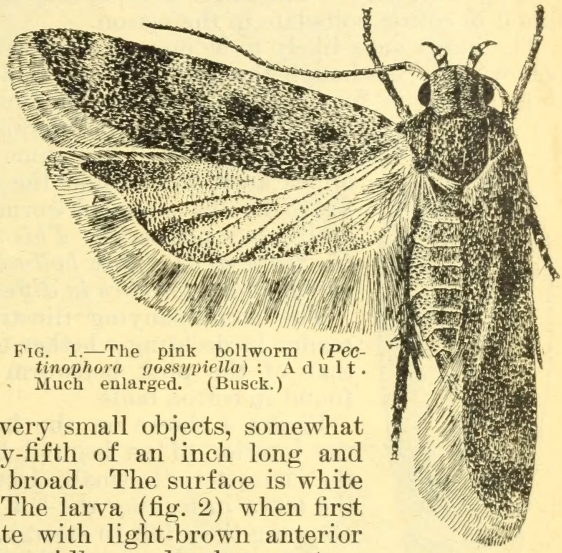

FIG. 1.—The pink bollworm (*Pectinophora gossypiella*): Adult. Much enlarged. (Busck.)

The pupa (fig. 3) is about two-fifths of an inch in length, reddish brown, the posterior end pointed and ending in a hooklike process.

Several insects are found in bolls of cotton in the United States which may be mistaken for the pink bollworm. One of these is the so-called pink cornworm or scavenger bollworm (*Pyroderces rileyi* Walsingham), which frequently is found in decaying bolls, especially those which have been injured by disease. It has not been known to attack healthy bolls. It does not normally make its way into the seed, and this fact will help in distinguishing it from the pink bollworm. Another insect which may be mistaken for the pink bollworm is the common bollworm of cotton (*Heliothis obsoleta* Fab.). This is the same insect that feeds on corn and is known in some parts of the country as the corn earworm. It bores holes through the carpels of the boll, feeds for a short time, and then proceeds to another boll. In the early stages it sometimes assumes

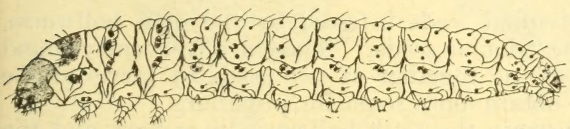

FIG. 2.—The pink bollworm: Outline drawing of larva, showing structure. Much enlarged. (Busck)

a somewhat pinkish color. It may be distinguished from the pink bollworm by its habits, especially by the fact that it does not feed altogether in the interior of the bolls and that it is not found within the seeds. When full grown it is much larger than the pink bollworm, measuring about 2 inches in length.

There is also an insect which feeds in plants known as "nigger heads" (*Rudbeckia* spp.), and another feeding in cat-tails (*Typha* spp.), both of which are sometimes mistaken for the pink bollworm (*12, pp. 813, 831*). The latter is especially confusing, as it is often found in cotton bolls late in the season.

The insect most likely to be mistaken for the pink bollworm is the boll weevil. Although the boll weevil is sometimes found in seeds, it generally is found feeding within the interior of the boll. It discolors the fiber considerably, and this causes the interior of the boll to assume a more or less decayed appearance, quite unlike the appearance of bolls infested by the pink bollworm, in which decay generally does not occur. *This so-called cleanliness of the work of the pink bollworm is one of the most useful characteristics in differentiation.*

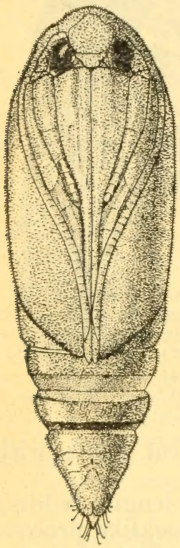

FIG. 3.—The pink bollworm: Pupa. Much enlarged. (Busck.)

The accompanying illustrations will assist the reader in deciding whether the work in question is that of the pink bollworm or some other insect found in cotton bolls.

Figure 4 shows on the left the appearance of the interior of an injured boll, and on the right the characteristic small circular opening made by the larva in leaving the boll or for the purpose of allowing the adult to emerge.

Figure 5 shows on the left the characteristic opening made by the ordinary bollworm (*Chloridea obsoleta*). It is of large size and surrounded by a raised margin. The exit holes of the pink bollworm, shown on the right, are much smaller, more regular, and without raised margins.

Figure 6 shows the appearance of locks of cotton bearing the typical injury caused by the pink bollworm.

Figure 7 shows individual seeds infested by the pink bollworm. In the lower line are the "double seeds." These are frequently found as the result of the webbing together of two seeds by larvæ of the later stages in order to obtain more room for pupation.

Figures 8 and 9 illustrate the pink bollworm in a burr and the typical opening made by this insect when it makes its way from one lock to another.

Although these descriptions may help in enabling anyone to determine whether the pink bollworm is present in a cotton field, it will always be best to send any specimens to an entomologist for authoritative determination. It is extremely important that any possible infestation by this insect be brought to attention at the earliest possible date, that prompt eradicative measures may be taken.

Under the authority of the Federal Horticultural Board, August Busck spent a number of months in the Hawaiian Islands in 1915

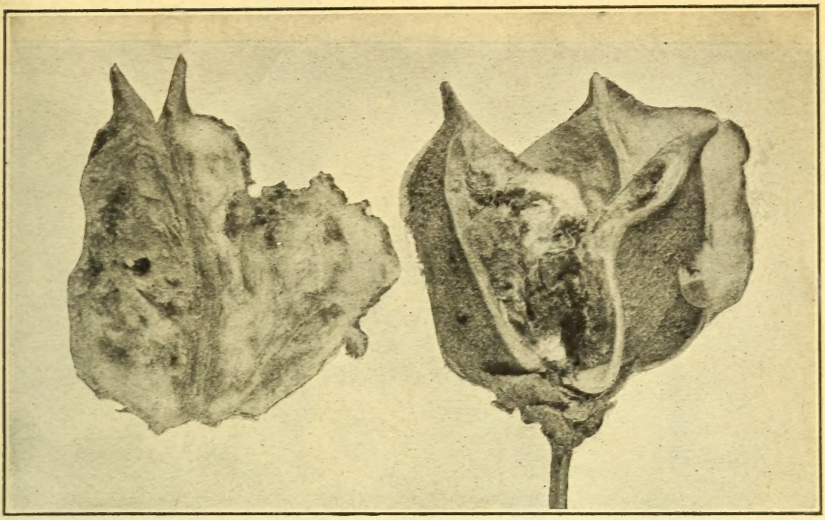

FIG. 4.—Exit holes of pink bollworm in cotton bolls

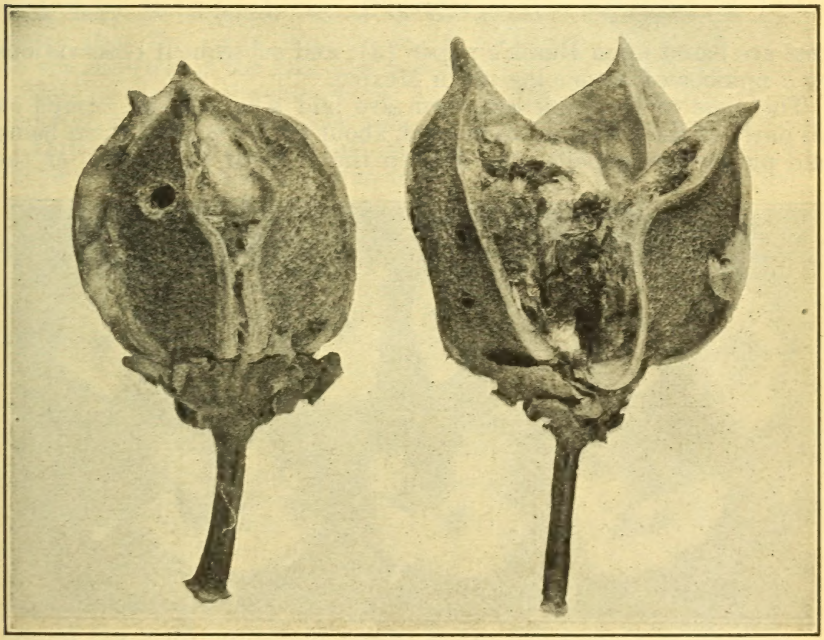

FIG. 5.—Two bolls showing distinction between exit holes of the ordinary bollworm or corn earworm (*Chloridea obsoleta*) and those of the pink bollworm (*Pectinophora gossypiella*). The large hole in the boll to the left was made by the ordinary bollworm; the two small ones in the boll to the right are typical of the pink bollworm

studying the life history and habits of the pink bollworm. The following statements regarding the life history and habits of the

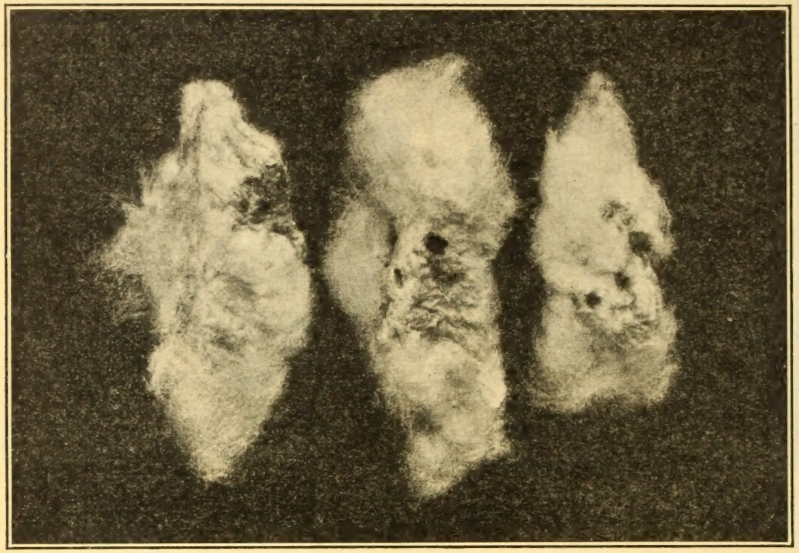

FIG. 6.—Cotton locks showing typical injury by the pink bollworm (*Pectinophora gossypiella*)

pest are based upon Busck's paper (*3*), and subsequent observations by a number of entomologists in Mexico.

The eggs of the pink bollworm are laid singly or in groups on all parts of the plant above ground, about 50 per cent of them being laid on the green bolls. In Mexico the favored position is at the

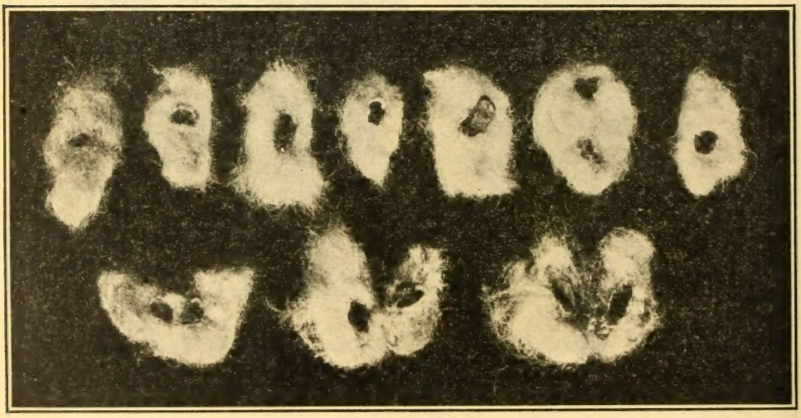

FIG. 7.—Cotton seed containing pink bollworms, opened to show the cells. Both the single and double seeded cells are shown, the double seeded ones being broken apart

base of the boll, between the boll wall and calyx. Often more than 50 eggs and shells have been found on a single boll. It is estimated

that a female will deposit in the neighborhood of 100 eggs. These hatch in from 4 to 12 days.

The larva, on hatching, proceeds to bore its way into either a square or a boll. Squares are preferred early in the season, before the green bolls have become three-fourths grown. The square, even though it contains a larva, usually develops into a bloom. If the larva has attained nearly full development before the bloom opens it webs the ends of the petals together, and on opening they do not flare out normally; the bloom presents a rosetted appearance and is easily distinguished as infested. The infested bolls sometimes become recognizable by a reddish or blackened discoloration which follows attack. Close examination will also reveal the small entrance holes of the larvæ. But the only conclusive evidence of infestation is the larva within the boll, as disclosed by dissection.

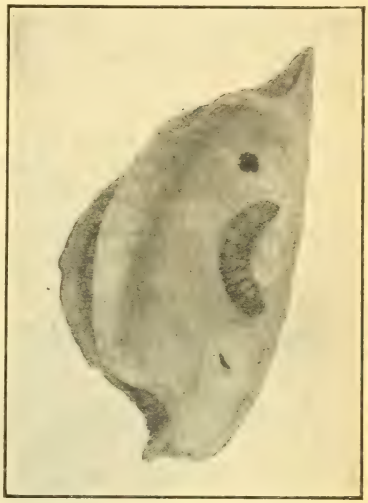

FIG. 8.—Pink bollworm on carpel of cotton boll, which shows also typical hole made by worm while traveling from one lock to the next

The food of the larva is the seed within the boll. It devours one seed and generally proceeds to the next one above. Ordinarily a single larva does not make its way outside of the lock which it first invades, but occasionally the adjoining lock may be entered. It is to be noted that the larva restricts itself to the interior of the boll and never makes its way to the outside for the purpose of reaching another boll.

During the summer the full-grown larva either cuts a hole in the outer boll wall for the emergence of the moth and pupates immediately under it, or drops to the soil and pupates within the surface layer of soil or under trash on the surface. In the fall the majority of the larvæ remain in the bolls for hibernation. Often the larva protects itself by webbing two seeds together, the attachment being made to the openings brought into contact by the insect. These "double seeds" are characteristic of the work of the insect. Since usually they are not destroyed in the process of ginning, they furnish the best means of determining quickly whether any lot of seeds is infested.

During the summer the larval stage occupies from 20 to 30 days. Late in the season this stage may be more or less indefinitely prolonged, and pupation correspondingly delayed (*9, p. 9*). It is this feature in the life history of the pest which has facilitated its carriage to many remote quarters of the earth. As this longevity is one of the most important points in the life history of the insect a summary of the existing records concerning it is given in Table 1.

TABLE 1.—*Longevity of resting larvæ of the pink bollworm*

Country	Authority	Conditions under which kept	Longevity
			Months
Egypt	Gough [1]	Stored seed	27
Do	do.[1]	do	16
Do	Ballou [2]	do	24
Do	do.[3]	do	30
Do	do.[4]	do	31
Do	Willcocks [5]	Natural conditions	22
Hawaii	Busck [6]	Stored seed	18
Mexico	Loftin, McKinney, and Hanson [7]	do	12
Do	Ohlendorf [8]	Stored bolls [10]	Over 16
Do	Unpublished [9]	Stored bolls	16¾

[1] (*9, p. 9.*)
[2] (*1, p. 11.*)
[3] (*1, p. 16.*)
[4] (*2, p. 264.*)
[5] (*21, p. 154.*)
[6] (*3, p. 356.*)
[7] (*14, p. 16.*)
[8] (*17, p. 10.*)
[9] Unpublished manuscripts, U. S. Department of Agriculture.
[10] Resting larvæ in stored seed lived 15 months.

After a variable time, as has been indicated, the larva transforms into a pupa or chrysalis. The pupal stage lasts from 6 to 20 days, at the end of which the moth emerges. The life of the moth is rather

FIG. 9.—Typical holes made by pink bollworms through cotton-boll carpels

short. Under favorable conditions Busck succeeded in keeping some specimens alive for 32 days, but under the same conditions the great majority of the insects died in from 14 to 20 days.

The moth is seldom seen in nature. It habitually hides during the day under stones or brush. The normal time of flight is from 6.30 to 8 p. m. Although apparently capable of prolonged flight, the moths prefer to go no farther than the first cotton field. They are so quiet in their habits and so easily overlooked that many may occur unnoticed in the field.

The question of the extent to which the pink bollworm moth is attracted to lights is one which has been discussed extensively in the literature. In Hawaii, Busck (*3*) found that there is no attraction to lights under the conditions prevailing where he worked. Loftin, McKinney, and Hanson (*14*) made extensive tests in the Laguna region of Mexico, but failed to find any definite indications of such attraction. Fletcher (*7*), working in India, and Matsumoto (*16*), working in Korea, also failed to find much attraction to lights. However, several Egyptian investigators, including Gough and Willcocks, have found moths coming to lights under certain conditions (*1, p. 238.*) Gough captured a large number of specimens in light traps in the warehouse in which cottonseed was stored, and Willcocks with 18 traps captured about 19,000 moths in three months, but did not consider that this was enough to warrant the use of light traps as a control measure.

It is very probable that the differences in the observations are due to the varying conditions under which they were made. It is well known that insects are much more strongly attracted to lights under certain climatic conditions than under others.

The explanation of the Egyptian observations may perhaps be found in the climate of the locality in which they were made. It is also possible that the quality of the lights used by the various experimenters may help to explain the discrepancies. At any rate, it seems to be clearly indicated that under no known conditions is there attraction sufficient to be of any importance in control work.

Considerable attention has been paid in various countries to the food plants of the pink bollworm. In Egypt the insect has been found breeding in okra, hemp, and hollyhock. There are similar records from India. In the Hawaiian Islands it has been found in various species of cotton and in *Hibiscus youngianus*. From Brazil there are records of its occurrence in *Cochlospermum insigne* and *Bombax monguba* (*4*).

The most extensive studies of the alternative plants of the pink bollworm have been conducted in Mexico (*14*). Okra and hollyhock were frequently found infested, as was a native desert plant, *Hibiscus cardiophyllus* Gray. A large series of malvaceous plants from the United States were planted for the purpose of observation. The following eventually became infested in greater or lesser degree: *Hibiscus coccineus* Walt., *H. militaris* Cav., *Kosteletzkya virginica* L., *Hibiscus syriacus*, and *Malvastrum americanum* (L).

Several experiments were performed to determine whether the pink bollworm could live over from year to year when supplied with any of these alternative food plants. Special attention was paid to okra. In no case did the insect live under such conditions. This result appears to have been due primarily to the fact that the seed pods of okra and related plants crack open on drying, so that the larvæ webbed up in them drop to the ground and become subject to the influence of moisture and the attacks of enemies. It is more than likely, however, that under some conditions the insect may be able to perpetuate itself on these plants.

In Texas and Louisiana, where noncotton zones have been maintained for the purpose of stamping out the pink bollworm, the

alternative plants have been disregarded, for the reason that most extensive searches have failed to disclose any of the insects in any of the malvaceous plants growing in such zones. Certainly the apparent success of the noncotton zones (and clean-up measures) in eliminating the infestation minimizes the importance of the existence of the pink bollworm on plants other than cotton under such conditions as have prevailed in the United States. It must be remembered that there has never been any heavy infestation of cotton by the pink bollworm. The number of moths produced has in every case been exceedingly small. With a very heavy infestation the results might have been very different, since out of a larger population of moths there might be a sufficient number of aberrant individuals to continue the species on other plants.

NATURAL ENEMIES

The pink bollworm has a number of insect enemies wherever it occurs. In the Hawaiian Islands Busck (*3*) found at least five species attacking it. Other species have been recorded from Egypt, Brazil, and India. In Mexico, early in July, 1921, as high as 33 per cent of the pink bollworm larvæ in blooms were killed by parasites. Two species of Hymenoptera, *Microbracon mellitor* Say and *Habrobracon gelechiae* Ashm., were responsible for this unusual destruction.

By far the most important enemy of the pink bollworm is a small mite known as *Pediculoides ventricosus* Newport. Its attack is confined almost entirely to pink bollworm larvæ in stored seed. It is a common enemy of insects and occurs throughout the world. It has apparently increased to a very considerable extent in Egypt, but does not seem likely to be sufficiently abundant at any time to serve as an important agent in controlling the pink bollworm. Neither do the available records indicate that any insect or mite enemies of the pest are likely to be of any practical importance in controlling it.

It is interesting to note that the mite to which reference has been made also attacks human beings. In 1914 large quantities of Egyptian cottonseed were shipped to London. The laborers employed in handling this seed became affected with a rash of the skin caused by the punctures of the mite. The irritation was severe and resulted in a strike for higher wages. The writer has learned from E. C. Green that in Brazil, since the establishment of the pink bollworm there, children who play about seed houses soon become affected by a dermatitis which probably is the same as that which has been found to follow the attack of the mite in other parts of the world.

NATURE AND EXTENT OF DAMAGE

The pink bollworm affects cotton production in several ways. In the first place it destroys a certain number of bolls or portions of bolls, causing the lint from them to be short and kinky. (Fig. 10.) The injury, however, is not limited to the yield and quality of lint. The crop of seed is correspondingly reduced, and what seed is obtained is of light weight and poor grade. In the crushing of Egyptian seed in England it was found that the oil content was

lower than normal by about 20 per cent, and that the oil actually obtained was dark in color and of comparatively low value. The work of the insect is also of importance in connection with seed for planting. The percentage of germination is naturally low and much larger quantities must be planted to obtain a stand.

From what has been said it is evident that the pink bollworm must be of interest to all classes of persons concerned in the cotton trade as well as to those engaged more especially in the cultivation of the crop and the utilization of the seed.

Accurate information concerning the damage by the pink bollworm in Egypt is contained in a paper by L. H. Gough (*10*). This investigator conducted studies in lower and middle Egypt to determine the relative number of bolls attacked by the pink bollworm. Samples, each of 100 green bolls taken at random in fields in various localities, were sent to Cairo, where they were given

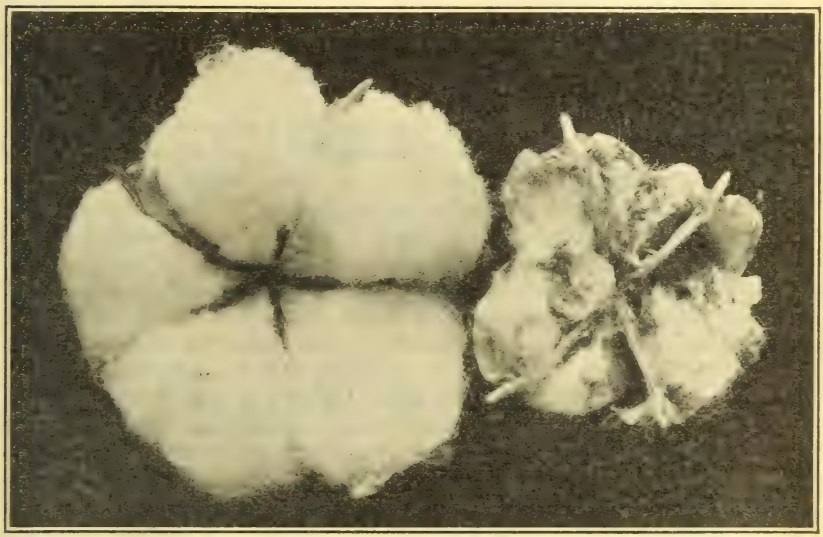

FIG. 10.—At left, normal cotton boll; at right, boll injured by the pink bollworm

very careful examination. The total number of bolls examined was more than 106,400, and the examinations were continued from July to November, 1916. The following are among the results of this investigation:

Percentage infested during July, less than 10.
Percentage infested during August, from 5 to 25.
Percentage infested during September, from 25 to 75.
Percentage infested during October, from 75 to 85.

These figures show in a very striking manner the great damage of which the pink bollworm is capable, and may be taken as a fair indication of the injury which would be done in the United States if it were allowed to spread here, as the seasonal conditions here are similar to those in Egypt. In short, they show that approximately 20 per cent of the August bolls and 50 per cent of the September bolls would be destroyed or rendered practically valueless by the insect. They further illustrate the rapid increase of infestation of green

bolls with the advance of the season, and indicate the possibility of a severe reduction of yield, particularly in all late-maturing cottons where the second and third pickings are important. Fortunately for Egypt, one of the principal varieties of cotton grown there, the Sakellarides, matures its crop early and yields most of its cotton with the first picking. In spite of this favorable circumstance, however, and of expensive control operations enforced by the Government, a very conservative estimate by experts indicates that this insect causes a loss of at least 17 per cent to the Egyptian crop. In the Hawaiian Islands the pink bollworm has prevented the development of the cotton industry, which at one time showed considerable promise.

In Brazil, through correspondence with the governors of the principal cotton-producing States of the Republic, the minister of agriculture collected data for an estimate of the damage to the cotton crop caused by the pink bollworm in 1917. The loss reported ranged from 30 per cent of the crop in the State of Alagoas to two-thirds of the crop, or 30,000 metric tons, in the State of Ceará.

DAMAGE IN MEXICO

Special effort has been made to ascertain the degree of damage which the pink bollworm causes the cotton crop in the Laguna district of Mexico. In making the estimates two plans have been followed, one being to send experienced crop reporters to the Laguna, who collected data according to the plans followed in estimating injury to the crops from various causes in this country. Planters were interviewed and the consensus of their opinion as to the actual loss was determined. The other method consisted in estimating the quantity of cotton left unpicked in the fields on account of the injured bolls passed over by the pickers. In Mexico there are no important causes other than the pink bollworm which render bolls unpickable. The relation between the number of unpicked bolls and the number picked, as shown by the burrs remaining on the plants, has been taken in a general way to indicate the loss. This method is only a rough approximation; its accuracy will vary from year to year because, regardless of the degree of actual damage, the fields will be picked more thoroughly in years when the price is high than when it is low.

The actual injury caused by the pink bollworm in 1917 was investigated by a joint body representing the Mexican and American commissions, which visited many plantations in the Laguna. It reported that the loss to the crop of 1917 chargeable to the pink bollworm was not less than 30 per cent.

In 1919 a very special study of the various forms of injury was made (*14*). It was determined that the injury could be classified approximately in the following manner:

(1) Loss in squares and blooms; of 343 normal blooms observed, 40.8 per cent dropped off without setting bolls; of an equal number of infested bolls 67.6 per cent dropped off. An undetermined loss was also due to early shedding of infested squares.

(2) Loss in pickable cotton; the lint suffered deterioration in quality, the seed was reduced 6.9 per cent in weight, and the oil was unfavorably affected in both quantity and quality.

(3) Loss in nonpickable cotton; 19.98 per cent of the entire crop was rendered unpickable.

On the basis of the foregoing data the loss for the crop of 1919 was calculated at 20.89 per cent. In 1920 a similar estimate showed a total loss of approximately 38 per cent of the crop.

In 1921 the quantity of nonpickable cotton was calculated at 12.8 per cent, and in 1922 at 7.97 per cent. The losses through shedding and other causes were not estimated for these years. On account of the high price of cotton in both years, the fields were undoubtedly picked cleaner than usual. It is therefore probable that the actual losses were not materially lower than in other seasons.

In 1923 the loss was calculated at 16 per cent. Because of peculiar conditions, including a lack of rains during the growing season, it was evident that the damage was less than normal.

A study of the damage in the Laguna by expert statisticians was conducted by H. H. Schutz and E. S. Haskell, of the Bureau of Agricultural Economics. The following is quoted from their report:

Estimated losses to cotton crops caused by cotton pink bollworm, Laguna district, Mexico, 1915–1921

Year	Number of records or estimates	Average loss	Range of losses	Year	Number of records or estimates	Average loss	Range of losses
		Per cent	*Per cent*			*Per cent*	*Per cent*
1915	6	25.0	5 to 50	1919	27	19.0	2 to 50
1916	6	25.0	5 to 40	1920	36	30.4	4 to 70
1917	9	22.1	5 to 60	1921	39	22.4	3 to 70
1918	20	20.2	0 to 40	Average		23.4	

It was stated by the Laguna planters that formerly practically all cotton made before the first killing frost in the fall was No. 1 (good, middling, or better), and that picked later was No. 2 or No. 3, with but a small difference in the prices of the first two grades; however, the difference in price now runs at times as high as 11 cents per pound, depending upon the percentage of pink bollworm infestation.

On account of the number of breaks and loss of time in retying the ends, some of the spinners dislike to use late-picked Laguna cotton. Mauro de la Peña, manager of the Fabric La Fé Torreon, made tests with normal lint, and lint injured by the pink bollworm. Using a standard English dynamometer, the lint having been spun into 120-yards lengths of No. 18 thread, the normal cotton showed a resistance of 92 pounds, whereas the damaged, in three tests, offered resistance of 68, 75 and 72 pounds.

It is thought that from September, 1918, to August, 1919, the seed produced in the Laguna suffered no appreciable loss in weight, but in the following season 15 to 50 per cent of the seed was practically barren; this was particularly true of all but the early seed. The quantity and quality of oil produced is naturally proportional to the quantity and quality of seed produced. The percentage of undeveloped and worm-eaten seed in the late picking causes a reduction in the quality as well as the quantity of oil. The resulting oil is darker, and more residue remains in the process of refining; the cake is dark and carries an odor offensive enough to affect the animals to which it is fed.

One oil-mill operator estimates that the percentage of oil normally averages 17, that of cake 44, and that of hulls 35; and that the loss in oil from seed of the 1919-20 season was 0.5 point, and that for the following season 1 point. Another oil mill reports that the percentage of oil was formerly 16, but that now, because of injury caused by the pink bollworm, it is but 13½. He also states that even the first or early picking yields but 15 per cent of oil, and that this is appreciably infested; further, that 25 to 30 per cent of the seed produced late in the season is almost worthless, and yields only 10 to 11 per cent

of oil. The 1920 seed handled by this mill averaged 13¼ per cent of oil; the 1921 seed, 14 per cent. Good seed formerly weighed, on an average, 25 tons per carload; now a carload is found to weigh but 21 to 22 tons.

PRECAUTIONS TAKEN TO PREVENT THE INTRODUCTION OF THE PINK BOLLWORM INTO THE UNITED STATES

With the approval of the plant quarantine act on August 20, 1912, the Department of Agriculture for the first time obtained authority to regulate the importations of plants and plant products from foreign countries and to take the steps necessary to prevent the introduction of injurious insects and plant diseases by such importations. The pink bollworm was one of the first insects to be considered after the plant quarantine act went into operation. Its foreign status and its menace to American cotton were first brought to the attention of the Federal Horticultural Board in April, 1913, and on May 20 of that year a formal hearing was called at Washington to consider the advisability of prohibiting the importation of cottonseed from all foreign countries. A quarantine was promulgated on May 28, 1913, to take effect on July 1 of that year. This quarantine forbade the importation into the United States of cottonseed of every species and variety, and cottonseed hulls from any foreign locality and country excepting the Imperial Valley in the State of Lower California in Mexico. The importation from this region in Mexico was covered by regulations. The importance of this action was shown in May, 1913, by the receipt in Arizona of a shipment of 500 pounds of Egyptian seed which was found to have an infestation by the pink bollworm of about 20 per cent. Thanks to the quarantine law of Arizona and the activity of A. W. Morrill, the State entomologist, the whole shipment was destroyed by fire.

A little later (August 18, 1913), on the recommendation of experts of the Bureaus of Entomology and Plant Industry of this department, this quarantine was amended to provide, under regulation, for the entry, for milling only, of cottonseed from the States of Nuevo Leon and Tamaulipas, Mexico. A still later amendment permitted the introduction of seed from other of the northern States of Mexico.

The reasons advanced for allowing the regulated entry of Mexican cottonseed were that no insects which were not found in the United States were known to occur in Mexico, and that the culture of cotton there is more or less continuous with that in the United States. The absence of any cotton pests in the Republic of Mexico which did not occur in the United States at that time had been established by field inspections by several of the entomologists of the department.

To protect the United States from the possible entry of the pink bollworm from the Territory of Hawaii, a domestic quarantine was promulgated June 24, 1913, prohibiting the importation of cottonseed and cottonseed hulls from this territory.

It was thought that the United States was sufficiently safeguarded against the pink bollworm by the quarantines against cottonseed as such, but it soon came to notice that considerable quantities of seed were coming to the United States in bales of lint. A careful examination of picker waste from a large number of bales of Egyptian cotton was made. It was found that considerable numbers of seeds passed around the rollers in the gins and some between

the roller and the knife through small openings caused by wear. The waste from 37 bales which was examined showed sound seeds, some of them infested, varying from 27 to 600 per bale. The average per bale was 215. The variation in the different bales depended upon the grade of the cotton, the lower grades having many more seeds than the better ones. It was estimated on the basis of the examination of waste from the 37 bales that over 16,000 live larvæ of the pink bollworm were being brought to the United States each year, of which several hundred went to the mills in the Cotton Belt.

It thus became evident that a quarantine which did not take into consideration the seeds in bales of lint was inadequate. Consequently in May, 1914, a public hearing was held to discuss various means of protection. The different proposals made were that foreign cotton be excluded altogether from the United States; that it be admitted only under a guaranty that all seeds had been eliminated, or that the cotton had been disinfected; that it be allowed to proceed only to mills outside of the Cotton Belt; and that it be sent to southern cotton mills only after a period of storage of 18 months or more in northern localities. At the public hearing, and subsequently through conferences with members of the cotton trade and representatives of manufacturing associations whose assistance was very valuable to the department, it became evident that there were insuperable obstacles in the way of any of the plans mentioned. It therefore became necessary to make an exhaustive study of the possibility of destroying any infestation which might be found in the bales of lint. The use of cold was found to be impracticable. The use of heat was also impracticable on account of the time necessary to penetrate the highly compressed bales of Egyptian cotton and on account of the increased danger from fires when bales which had been heated were opened in the mills.

About this time E. R. Sasscer, of the Federal Horticultural Board, and Lon A. Hawkins, of the Bureau of Plant Industry, had been conducting some experiments in the destruction of insects in various plant products by fumigation in a vacuum. It was found that the killing power of hydrocyanic-acid gas was increased enormously in vacuum and it thus became possible to reach certain classes of insects which heretofore had been uncontrollable. It therefore seemed possible that the vacuum process might be utilized in the fumigation of bales of cotton without necessitating their opening. A small experimental plant was established by the board at Washington and a long and what turned out to be a most interesting series of experiments was begun by Sasscer.

While this investigation was in progress an order regulating the entry of all imported lint cotton was promulgated by the Secretary of Agriculture April 27, 1915, effective July 1, 1915, and a domestic quarantine regulating the movement of cotton lint from the Territory of Hawaii to the mainland was promulgated June 11, 1915, effective on and after July 1, 1915. Under this order and quarantine, tentative regulations were issued governing and restricting the entry of foreign cotton and also providing for the screening of all rooms or buildings in which foreign cotton was kept

and the daily burning of all grades of mill waste in which seeds of such cotton might be found. A corps of inspectors was employed and, to insure the faithful following of regulations, frequent examinations were made at the mills where foreign cotton was used. In general, sympathetic cooperation was obtained. This was especially noticeable in the case of southern mills, the owners and managers of which seemed to realize the danger of introducing the pink bollworm and complied with the orders and regulations of the Federal Horticultural Board in the most hearty and public-spirited manner.

In the experiments with vacuum fumigation of lint cotton conducted by Sasscer, under the direction and with the advice of the Federal Horticultural Board, tests were made with variations in the dosage of cyanid, the degree of vacuum, the length of exposure, the temperature, and the depth of penetration. Steel tubes pointed at one end were provided. These had perforations near the point and were sealed in such a manner as to be perfectly airtight at the other end. Insects were placed within them, and the tubes were then driven into the bales. After the experiment was performed the insects were removed for examination. In this way the exact effect of the fumigation under all varying conditions at different depths within the bales could be determined. At the same time chemical tests were made by the Bureau of Chemistry of this department to run parallel with the tests with insects. These chemical tests confirmed the rapid penetration of the gas.

As a result of a suggestion made following a conference of a committee of cotton manufacturers with the Federal Horticultural Board, the then Office of Markets and Rural Organization of this department conducted a series of manufacturing tests with cotton which had been fumigated with hydrocyanic-acid gas to determine whether the fumigation by this agent would cause any injury to cotton fibers. The results of these tests indicate that such fumiga tion of cotton did not cause any deterioration of the cotton, either as to percentage of waste, spinning qualities, tensile strength, or the bleaching, dyeing, or mercerizing properties of the cotton (*5*).

In the first series of experiments various insects more or less related to the pink bollworm, but which are native to the United States, were used. After the preliminary work was done and the probable requirements for destroying any insect in the bales of lint were determined, it was decided to add a series of experiments with the pink bollworm itself. For this purpose, under extreme caution to avoid escape, a number of insects were brought from the Hawaiian Islands. The results in all essential respects were similar to those that followed in the case of the insects treated previously.

As the result of all of this work, which taxed the ingenuity of the investigators engaged in it, it was found feasible on a commercial scale to fumigate densely compressed bales of cotton and kill any insect which might be inside.

On March 10, 1916, the fumigation of all bales of foreign cotton arriving at the United States was required as a condition of entry. Advance notice had been given to the importers and others concerned. In spite of considerable difficulties in obtaining materials and in working out mechanical problems, large plants were erected in a remarkably short time and became available for use on the date mentioned. Two of these plants were erected in Boston and

one in Oakland, Calif. A little later two additional plants were erected at New York City and one at Newark, N. J. Plants are now available at Seattle, Wash., Oakland and San Francisco, Calif., and Astoria and Portland, Oreg. These establishments have a capacity sufficient to handle all of the imported cotton without any special delay. The larger plants have a capacity of upward of 1,000 bales per day.

The procedure to be followed in the fumigation of foreign cotton is given in an order of the Federal Horticultural Board (*19*)[6].

Later investigations led to the placing of restrictions on certain kinds of cotton waste, cotton wrapping material and cottonseed products. On April 11, 1916, the collector of customs at Norfolk, Va., telegraphed the board that some 189 tons of cottonseed from Lagos, West Africa, constituted a portion of the cargo of the British steamship *Appam*, brought to Newport News as a German prize of war. In coöperation with the Office of Markets the board took immediate steps to dispose of this seed, which was found to be infested by the pink bollworm. A provisional sale had been made by the admiralty board to the proprietor of an oil mill in South Carolina. This was set aside as soon as the danger of introducing the pink bollworm was explained. After considering a number of methods of disposing of this seed, it was finally decided to have it treated with sulphuric acid and thus made available as a fertilizer. Through the coöperation of one of the largest manufacturers of fertilizers this was done with the utmost dispatch. The entire lot of 4,000 bags of seed was placed in sulphuric-acid vats within four days from the time the presence of the seed at Newport News became known to the department. As an additional precaution the two holds of the *Appam* which contained the seed were fumigated with a heavy dose of hydrocyanic acid gas, and the docks, lighters, and trucks, as well as floors and platforms, were thoroughly cleaned of any scattered seeds.

To guard against the possibility that the pink bollworm had escaped prior to the treatment which has been described, repeated inspections were made later of the cotton fields near Newport News, which are at a distance of about 10 miles. No traces of infestation have been found, and it now seems certain that the establishment of the insect from this seed was prevented.

DISCOVERY IN MEXICO

Earlier in this bulletin attention has been directed to the fact that when the quarantine against foreign cottonseed was placed in operation the State of Lower California, Mexico, was not included, and that subsequently cottonseed was permitted entry, for milling purposes only, from certain northern States of Mexico. The reason for this was that several of the entomologists of the department had been in northern Mexico and had found no traces of infestation by any insects other than those which are known to occur in the United States. These explorations were made some years previously, however, and it was thought desirable to make new examinations on ac-

[6] Detailed information as to the activities of the Federal Horticultural Board and its quarantine and other restrictive orders and regulations relating to cotton and cotton products, may be found in its service and regulatory announcements.

count of the suspicion that the pink bollworm or some other destructive pest might have been introduced in the meantime. Accordingly arrangements were made in 1916 to dispatch an agent to Mexico. Shortly before the time fixed for his departure the activities of the bandits became so great that the trip had to be postponed indefinitely. If it had not been for these circumstances the presence of the pink bollworm in Mexico would have been known some months before it actually came to the attention of the department.

On November 1, 1916, the department received from a planter in the Laguna district, who was then residing in Mexico City, a number of specimens of cotton bolls which had been attacked by insects. The sender was under the impression that the insect was the boll weevil, which, though introduced in the Laguna on numerous occasions, had, on account of climatic conditions, never been able to maintain itself. Several of the bolls were found to be infested by the boll weevil, but others showed the presence of the pink bollworm. The determination was first made by W. D. Pierce and confirmed by August Busck and other specialists of the Bureau of Entomology.

On November 3, 1916, the situation was considered by the Federal Horticultural Board, and on November 4 an amendment to the regulations, extending the quarantine to cottonseed and cotton from Mexico, was issued by the department. An investigation was immediately started to determine the extent of the infestation in Mexico and the number of shipments of cottonseed from that country to the United States. It was soon found that a large quantity of Mexican cottonseed had been shipped to mills in Texas during the season of 1916. In previous years no Mexican cottonseed had been shipped to the United States, and it was only the disturbed conditions in Mexico and the unprecedentedly high price of seed in the United States that caused the seed mentioned to be forwarded to this country.

In 1916 a total of 446 carloads of Mexican seed had been brought into Texas prior to November 4, all of which went to the mills at Beaumont, Pearsall, Kaufman, Hearne, San Antonio, Houston, Dallas, Wolfe City, New Braunfels, Grand View, and Alice. The quantities varied from 1 carload, which went to Wolfe City, to 114 carloads, which went to Beaumont. Ninety-three carloads were shipped to Hearne and 69 to Kaufman, both located in regions where cotton is cultivated on every plantation. The State authorities in Texas were notified and the Federal Horticultural Board began a campaign to expedite the crushing of the seed and the destruction of any scattered seeds about the premises. The cooperation with the State was brought about by Fred Davis, commissioner of agriculture, the entomologist of his department, E. E. Scholl, and the chief nursery inspector, E. L. Ayers.

DISCOVERY IN TEXAS

As the result of field examinations, the first specimen of the pink bollworm in Texas was discovered in Hearne on September 10, 1917, by Ivan Schiller, an inspector of the board. This was found in a small field adjoining the oil mill which had received Mexican cottonseed. Later four additional specimens were found, none of them more than one-fourth of a mile from the mill. On October 5 a

specimen was found in a field near the oil mill at Beaumont by inspector H. C. Millender, and on October 25 specimens were taken at Anahuac, in Chambers County, by H. S. Hensley. The first two of these infestations were undoubtedly due to the Mexican seed which had been shipped to the United States in 1916. The infestation in Chambers County, however, can not be attributed to such shipments. It was found to extend around Galveston Bay from Smiths Point to the vicinity of Texas City. It was heavier near the bay and diminished regularly toward the interior. After considerable investigation, in which all possible theories were weighed, the conclusion was reached that this infestation was probably due to Mexican bales of cotton which were shipped to Galveston in 1915. During this year several thousand bales of cotton from the Laguna in Mexico reached Galveston by way of El Paso. This cotton was on the docks at Galveston at the time of the hurricane of August, 1915. With several thousand bales of Texas cotton it was washed from the docks and distributed around the shore line, in some cases 75 miles away. Many of the bales were broken open by the force of the water. It is well known that Mexican bales contain large numbers of seeds, and cotton plants were found growing along the high-water line during the fall of 1915 and the spring of 1916. This theory, while not altogether satisfactory, is considered by August Busck, who has paid more attention to the study of the pink bollworm than any other entomologist, to be an adequate explanation of the present situation around Galveston Bay.

As soon as the presence of the pink bollworm in Texas was discovered, the Federal Horticultural Board, in cooperation with the Department of Agriculture of the State of Texas, undertook active measures to eradicate it. The work consisted at first of scouting to determine the limits of infestation, the destruction of any possible infestation remaining in the fields, and the safeguarding by various means of the cotton produced in the infested fields and in neighboring ones during the season of 1917.

The work of removing any possible infestation from the fields consisted in uprooting or chopping down the plants, the collection by hand of all locks or portions of locks which were found on the ground, and the burning of all the accumulated trash. In this work 1,624 acres of land in the vicinity of Hearne was cleaned, and 7,170 acres in southeastern Texas. The work was not confined to fields in which infestation was actually discovered, but included fields at a considerable distance beyond the outermost points found infested. It involved the employment of an average of about 500 laborers for the months of November, December, January, and February, and a portion of March. In many cases the laborers were assembled in camps and housed and provisioned by the department. In other cases, where the work was in the vicinity of towns, it was possible to employ local labor. The safeguarding of cotton products from the infested areas in 1917 consisted in the milling of the seed under supervision at certain mills selected because their construction would enable the work to be done with practically no danger of disseminating the pest. The baled cotton, as far as possible, was caused to be exported or shipped directly to northern mills.

COTTON-FREE ZONES

In 1917 the legislature of Texas passed an act intended to give authority to prevent the establishment of the pink bollworm in the State. By this act authority was granted to quarantine the districts in which the insect might be found, and to establish zones in which the planting of cotton might be prohibited. Under this authority, on January 21, 1918, the Governor of Texas quarantined the Hearne district as well as the territory found infested in southeastern Texas. In the case of Hearne the quarantined area included a territory within a radius of 3 miles from the mill. In the case of southeastern Texas the quarantined area included a safety zone, approximately 10 miles in width, covering the outermost points infested.

On February 25, 1918, following the recommendation of the commissioner of agriculture, the Governor of Texas issued a proclamation prohibiting the planting of cotton in the quarantined areas.

The finding of infestation by the pink bollworm in Mexico not far from Del Rio in the spring of 1918 made it necessary to place in operation another section of the Texas pink bollworm act. As a consequence a third noncotton zone was provided to include McKinney, Maverick, and Valverde Counties.

SPECIAL REGULATIONS AT MEXICAN BORDER

The risk of direct entry of the pink bollworm from Mexico by flight or by accidental carriage necessitated the provision in the regulations governing the entry from Mexico of cottonseed cake, meal, or other cottonseed products, including oil, that permits for such entry should be issued only for the products named coming from mills located in the Laguna district of Mexico. The object of this proviso with relation to Mexico is to deter the erection of mills near the border of the United States, with the consequent risk of escape of insects from seed brought for crushing to such mills near the border.

ORGANIZATION OF THE PREVENTIVE WORK OF THE DEPARTMENT OF AGRICULTURE

In general, the basis of the work in Texas and other States has been scouting to determine the location and extent of infestations. When this has been done noncotton zones are provided, with surrounding zones in which all cotton products are safeguarded as to distribution and use. Two years has been found a sufficient time for maintaining the noncotton zones, but the regulated zones are continued longer. As soon as infestation is found the fields are thoroughly cleaned by removing and burning all bolls, burs, and other material which might harbor the insect. This work extends far beyond the fields actually found infested and is carried on each year in the regulated zone surrounding any noncotton zone. Of course all noncotton zones are carefully scouted and all volunteer cotton destroyed.

It is probable that this clean-up work has been the most important factor in what seems now to have been a successful effort at eradication in large areas. No attempt has been made to reach such

larvæ as might be in the soil. Certainly the vast majority of the insects in the field in the fall and winter are in the bolls on the plants and in the bolls and trash on the ground, and these are effectively disposed of. The remaining insects are in a very unfavorable situation on account of the normally heavy winter rains, as experiments performed in Mexico show clearly that in moist soil the insect rarely if ever passes the winter alive.

The following is a general outline of the lines of preventive work begun in 1917 and continued up to the present time:

The exclusion from the United States of cottonseed from all foreign countries except the Imperial Valley of Lower California, Mexico. Cottonseed from Hawaii and Porto Rico has also been excluded.

The regulation and safeguarding of the entry of cottonseed products from all foreign countries and from Hawaii and Porto Rico.

Regulation of entry and disinfection of all imported cotton and cotton waste, and of burlaps which have been used as wrappings of foreign cotton, including such material from Hawaii and Porto Rico.

Survey, eradication, and control work in Texas and elsewhere, in cooperation with State authorities.

Regulation of rail and other traffic with Mexico.

Determination of distribution in Mexico and cooperation in control measures with the Mexican Government or local Mexican authorities.

Investigation in Mexico of the life history and habits of the pink bollworm, as a basis for control measures.

The work at the Texas border ports consists in the regulation of traffic from Mexico to prevent the importation, through accident or otherwise, of any Mexican cottonseed. It includes the inspection and disinfection of baggage, the cleaning or disinfection of all freight, express, and other shipments, except those which could not possibly carry infestation, restriction on the entry of railway cars from Mexico, regulation of the transfer of freight, express, and other shipments, certification of all cars or other carriers of merchandise as a condition of entry into the United States (excepting merchandise or other materials of strictly local origin), and the cleaning of domestic cars as a condition of receiving freight originating in Mexico for movement into the interior of the United States.

The work in Mexico consists in research and in cooperation with the Mexican Government and planters for eradicating the pink bollworm from that country. The loss which the pink bollworm has already shown itself capable of causing, and the fact that the cotton lands are owned by comparatively few persons, are grounds for hope that the main infestation in the Laguna district may be destroyed. Various conditions, however, have prevented any very definite progress along this line.

CHRONOLOGICAL SUMMARY OF INFESTATIONS

The origin of the Hearne infestation of 1917 has already been narrated. The area cleaned up comprised 1,624 acres. A noncotton zone was maintained for three years. No reinfestation has been found up to the present time.

The Trinity Bay infestation comprised 156 fields of the crop of 1917. A noncotton zone was provided in 1918, but, on account of a defective State law, it was discontinued during 1919. In the latter year 51 infested fields were found. In 1920, 1921, and 1922, noncot-

ton zones of limited size were established where infestation has been observed. In the scouting in the vicinity of these zones 28 fields were found infested in 1920, 1 in 1921, and none in 1922 or 1923. The clean-up operations were conducted in each of the years except 1918, at a total cost of $219,266.68.

In the Big Bend district the first infestation was found in the crop of 1918, and was evidently caused by the bringing in of cotton-seed from the interior of Mexico. Twenty-one fields, including some in Mexico, were found infested, all of which were cleaned up. A non-cotton zone was maintained there in 1919 and 1920. The infestation has continued, evidently owing to reintroduction of the insect from Mexico. The infested fields numbered 12 in 1921, 24 in 1922, and 33 in 1923. In 1921 and 1923 a part of the infested fields enumerated were in Chihuahua, Mexico. The Pecos Valley also was first found infested in 1918, to the extent of nine fields, as a result of the carriage of seed cotton from Big Bend. The area was cleaned up in 1918 and 1919, but no noncotton zone was established. Infestation has recurred in 1919, 1920, 1921, 1923, and 1924. Much labor has been expended in scout work.

TABLE 2.—*Number of man-days scouting and number of infested fields in each infested district for each crop to June 30, 1925*

District	1917		1918		1919		1920		1921		1922		1923		1924	
	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields
Texas:																
Hearne	164	5	471	0	650	0	505	0	369	0	172	0	255	0	0	0
Trinity Bay	645	156	829	0	1,796	51	2,006	28	1,518	1	891	0	1,225	0	1,030	0
Big Bend	0	0	4	[1] 21	(1)	1	0	0	22	[1] 12	27	24	66	[1] 36	167	62
Pecos Valley	0	0	555	9	1,123	1	850	15	299	21	386	0	421	5	631	15
El Paso Valley	0	0	103	0	158	0	339	14	78	9	261	4	406	1	397	1
Ennis	0	0	0	0	0	0	0	0	798	5	671	0	740	0	835	0
Marilee	0	0	0	0	0	0	0	0	340	2	461	0	611	0	612	0
Louisiana:																
Cameron	0	0	5	0	104	22	213	0	319	0	632	0	718	0	655	0
Shreveport	0	0	0	0	46	0	486	10	320	0	332	0	648	0	744	0
New Mexico:																
Mesilla Valley	0	0	0	0	0	0	240	[2] 5	27	[2] 6	77	[2] 1	231	0	260	0
Carlsbad	0	0	111	0	57	0	310	2	63	4	282	0	1,212	0	695	0
Totals:																
Texas	809	161	1,962	30	3,727	53	3,729	58	3,430	53	2,881	29	3,724	42	3,672	78
Louisiana	0	0	5	0	150	22	699	10	639	0	964	0	1,366	0	1,399	0
New Mexico	0	0	111	0	57	0	521	6	84	7	347	0	1,443	0	955	0
Total	809	161	2,078	30	3,934	75	4,949	74	4,153	60	4,192	29	6,533	42	6,026	78

[1] In 1918, 1921, and 1923, some of the fields enumerated under the Big Bend district were in Chihuahua, Mexico, but are here counted as being in Texas. In 1919 only a fraction of a man-day was devoted to scouting, and is not enumerated.

[2] In 1920, 1921, and 1922, a part of the fields here ascribed to the Mesilla Valley district were in El Paso County, Tex., and the totals by States are adjusted accordingly.

The infestation in the Cameron Parish district was discovered in 1919. There has never been any very satisfactory determination of its origin, but it is probably connected with the infestation in the Trinity Bay area. Twenty-two fields were found infested. A non-cotton zone was maintained effectively during the two following years and there has been no recurrence of the infestation. The area was cleaned up in 1919.

In the Shreveport district 10 fields were found infested in the crop of 1920, a result of seed shipped from the Cameron district prior to the discovery of infestation there. A noncotton zone was proclaimed in 1921 and continued through 1922, and there has been no recurrence of infestation. The area was cleaned up in 1920 and again during 1922 and 1923.

In the Mesilla Valley in New Mexico 5 fields were found infested in 1920. A clean-up campaign was begun, but it was discontinued when the extent of the infested territory in this district and in the adjoining El Paso district was determined. The infestation has continued.

In the El Paso Valley 14 fields were found infested in 1920. A clean-up campaign was begun, but it was discontinued on account of the general infestation in this and the adjoining Mesilla Valley and the proximity to Mexico. The infestation has continued.

The Carlsbad infestation was found in 2 fields in 1920. No clean-up was undertaken, and the infestation reappeared in 1921. There was no recurrence, however, in 1922 or 1923.

The Ennis, Tex., infestation, consisting of 5 fields, was found in 1921. It originated with the shipment of 14 carloads of cottonseed from New Mexico before infestation had been found there. The infested area was cleaned up in 1921, 1922, and 1923, and intensive scouting has not disclosed any reinfestation. A noncotton zone was maintained during 1922, the clean-up work for that year being conducted in the fields immediately outside of the small zone necessary under State law.

The Marilee infestation, consisting of two fields of the crop of 1921, originated in the reshipment from Ennis to Marilee of some of the New Mexican cottonseed which caused the infestation at Ennis. The area was cleaned up in 1921 and a noncotton zone was maintained during the following year. The area was cleaned again in 1922 and 1923. No reinfestation has occured.

The detailed records of the amount of scouting performed in each of these districts are given in Table 2 and the locations of the several districts are shown in Figure 11.

SCOUTING OUTSIDE OF KNOWN INFESTED DISTRICTS

The most important consideration connected with the attempt to control the pink bollworm in the United States has been whether all infestations have been discovered. A very large amount of scouting has been done in regions outside of the various areas in which the insect has been found, including numerous points to which possibly infested material has been shipped. Whenever an infestation has been found the shipments for the three preceding years which could possibly have introduced the insect have been traced to their destinations and careful scouting conducted. Of course, much attention has been given to scouting immediately outside of the various noncotton zones and regulated zones. Attention has been given to numerous reports of the occurrence of the insect which have been due to misidentifications. The routes of traffic from the Mexican border and the entire Mexican frontier have been thoroughly inspected. Table 3 shows the amount of this scouting in the various States where it has been done.

TABLE 3.—*Total number of man-days scouting and number of localities receiving attention in each State for each crop to January 31, 1924*

State	1917		1918		1919		1920		1921		1922		1923	
	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities
Central:														
Arkansas	0	0	19	9	0	0	0	0	37	2	0	0	0	0
Louisiana	0	0	17	10	539	49	1,717	76	1,328	36	1,212	31	977	10
New Mexico	0	0	111	2	57	3	528	12	84	18	347	10	1,058	31
Oklahoma	0	0	0	0	0	0	0	0	99	3	132	4	0	0
Texas	1,184	73	2,942	101	4,436	139	5,078	149	6,743	222	5,482	155	4,676	132
Mexico	0	0	(1)	1	48	21	0	0	208	21	57	4	63	16
Western:														
Arizona	0	0	43	14	60	23	0	0	316	7	215	9	0	0
California	0	0	0	0	0	0	14	3	204	13	61	6	0	0
Eastern:														
Alabama	0	0	25	2	67	6	0	0	16	9	0	0	0	0
Florida	0	0	0	0	0	0	0	0	10	6	0	0	0	0
Georgia	0	0	176	6	97	13	0	0	33	18	0	0	0	0
Mississippi	0	0	19	7	7	2	[2] 677	?	[2] 259	?	[2] 254	?	0	0
North Carolina	0	0	13	3	155	14	0	0	56	11	0	0	0	0
South Carolina	0	0	114	9	151	14	0	0	60	17	0	0	0	0
Tennessee	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Total	1,184	73	3,479	164	5,617	284	8,014	240	9,453	384	7,760	219	6,774	189

[1] Half a man-day or less

[2] Scouting by State inspectors

FIG. 11.—Map showing approximate location of infestations by the pink bollworm in Mexico and the United States: *A*, the Laguna district; *B*, Allende; *C*, the Trevino ranch; *D*, Santa Rosalia; *E*, Monclova; *F*, the Juarez Valley; *G*, the area in Chihuahua opposite Presidio and Brewster Counties, Tex.; *1*, Hearne; *2*, the Trinity Bay (Galveston Bay) area; *3*, the Big Bend area; *4*, the Pecos Valley; *5*, the Cameron Parish district; *6*, Shreveport; *7*, the Mesilla Valley; *8*, the El Paso Valley; *9*, Carlsbad; *10*, Ennis; *11*, Marilee. The Texas infestations at Hearne, the Trinity Bay area, Ennis, and Marilee, and the Louisiana infestations (the Cameron Parish district and Shreveport) seem to have been eradicated

PRESENT STATUS

The most noteworthy feature of the present status of the infestations which have been discovered in the United States is that they fall into two groups. One of these includes the infested districts found in western Texas and New Mexico; the Big Bend, Pecos, Carlsbad, El Paso Valley, and Mesilla Valley. All these show infestations continuing from year to year, with breaks of no great significance in some instances.

The other group includes all districts in which infestations have appeared in the United States, except those just named. They are six in number, four of which are in eastern Texas and two in western Louisiana. Following are the latest years in which infestation has been known to exist in the several districts: Hearne, 1917; Cameron, 1919; Shreveport, 1920; and Trinity Bay, Ennis, and Marilee, 1921.

In the eastern areas the success of the efforts at eradication appears to be strongly indicated. It is by no means certain that eradication has actually been accomplished in all these six districts, one of which included all or parts of seven counties. The extremely slight infestation, involving enormous difficulties in finding it, the longevity of the insect, and the insidious nature of its work, all suggest the possibility of a new infestation, to be eventually discovered in one or more of these districts. This possibility, however, is decidedly remote, so thoroughly has the scouting been done. In the more heavily infested places in the Trinity Bay area, the scouting included the examination of every boll and bur left on the plants after picking the cotton in fields planted after the termination of the noncotton zones. Such a possible infestation, however, would not be a serious matter, as the methods of eradication already worked out have been highly effective and are available at any time.

A great danger lies in the possibility that there may be infestations in unsuspected localities in the United States. The systematic search through practically the entire Cotton Belt by the Department of Agriculture and by the various State agencies has reduced this possibility to perhaps a negligible item. If any infestations are discovered, the perfection of the known methods of eradication will greatly facilitate, if not insure, their elimination.

Although the situation as regards the eastern infestations, many of which are in solid cotton territory, may be said to be satisfactory, the situation in the western areas is not so favorable. In these, on account of their proximity to Mexico, it has been impossible to take steps toward eradication, such as the establishment of temporary noncotton zones. Permanent noncotton zones would be required, and these have been impracticable on account of economic and other conditions. The danger of the spread of the insect from the western areas is by no means as great as might appear. In the first place, there is a barrier of 200 miles or more where no cotton is planted. The areas are also under quarantine, and all materials which could possibly carry the infestation from them are safeguarded. The volume of the infestation is greatly lessened by the requirement that all seed produced be disinfected by heat as a part of the process of ginning. Climatic conditions are also holding the insect to small numbers. The districts are of considerable elevation, ranging from

2,500 feet to about 4,000 feet above sea level. A careful study made in the El Paso Valley shows that there has been no noticeable increase in the amount of infestation during the last four years. These conditions greatly minimize the danger from the western infestation. The experience of several years shows that it is perfectly feasible to eliminate practically all danger of spread to other regions. There is a chance, however, that this spread may occur despite all precautions, and it is undoubtedly wise to maintain the restrictions with the utmost vigor.

On the whole, the conclusion seems to be warranted that the work done has resulted more succesfully than in the beginning was thought possible, and fully justifies the efforts and expenditures which have been made. This work must be continued, however, by preventing any possible recurrence in the districts where infestation has been found, by being ready to handle any undiscovered infestations in the Cotton Belt proper, by minimizing as far as possible the danger of the spread of infestation from the western areas, and by taking every precaution against new infestations from Mexico.

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